

by Joseph J. Carr

Open Channel

Dealing With AC Power Line EMI

Radio reception is many things to many people, but all forms of radio activity boil down to one thing: the signal-to-noise ratio (SNR) game. There is always some basic noise level caused by a combination of natural and man-made sources.

Figure 1 shows the fundamental situation in all radio reception problems. There is always some basic noise level caused by a combination of natural and man-made sources.

As society becomes more and more electrical, the man-made component becomes huge. But the actual amplitude of the noise signal is not nearly as important as the SNR, i.e., the relative strengths of the desired signal and the noise.

You will find that listening to weak signals on some frequencies, especially in the AM band or the "tropical" MW/SW bands, is made difficult or impossible by hash from the AC power lines.

Figure 1 shows four situations. There is a basic RMS noise level, which is labeled 0 dB. Four signals are present (A, B, C, and D). Signal A is clearly below the average noise level, so will not be heard. Some very skilled operators might be able to hear signal B because it sticks up just above the 0 dB noise level, but for most people it will remain a "... was that a signal or my imagination?" situation.

When the signal gets a little higher, say 3 dB above the noise floor, it becomes readable with a bit of discomfort and

annoyance. For most situations, "comfortable" listening requires an SNR of 10 dB, i.e., a signal that is considerably above the 0 dB noise floor.

Keep in mind that the absolute amplitudes of the noise and signals are not as important as the signal-to-noise ratio. Of course, as you start digging for weaker and weaker signals, the amplitude of the noise signal must be suppressed in order to get a usable SNR.

AC Power Line Noise

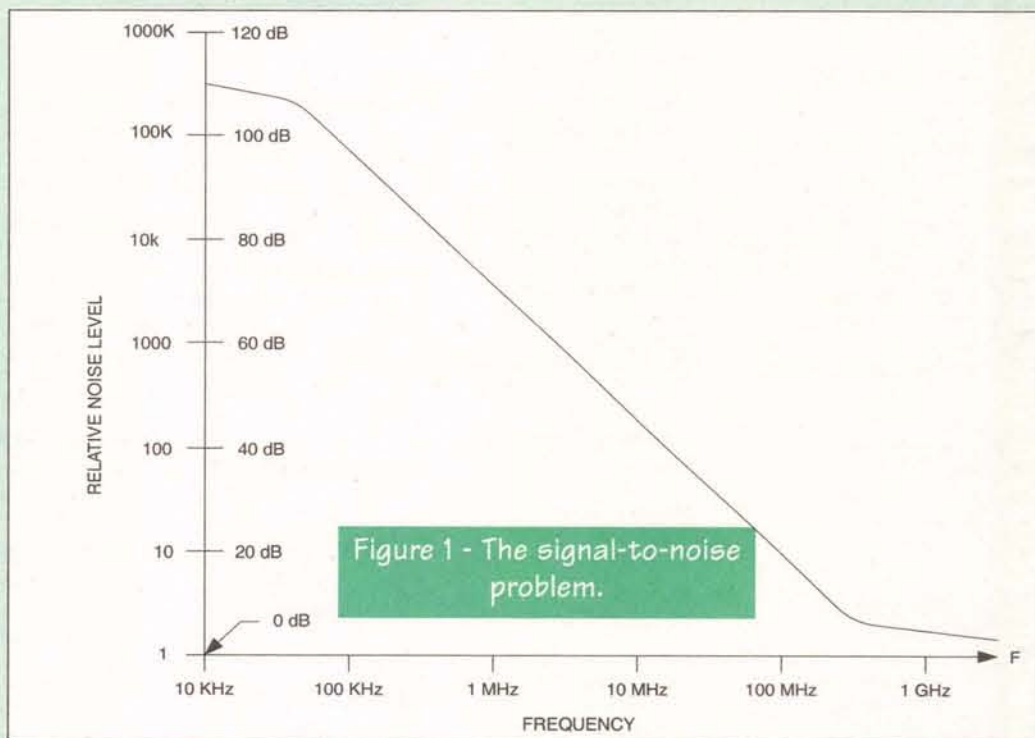
Perhaps the most common form of man-made noise afflicting radio and televi-

sion reception is from the AC power lines. When I first moved into my present home, my HF shortwave receivers were all but useless because of the high "hash" level of noise present.

The problem turned out to be a collection of "dimmer" switches that replaced the ordinary light switches. Those devices use a duty-cycle SCR circuit to lower the power level of incandescent lights, and the truncated waveform they produce is rich in harmonics (well into the HF bands!).

I replaced all six dimmers with conventional switches, and the noise level dropped enough decibels to be really impressive.

Over the years, I have found a large number of non-radio sources of interference to AM broadcast band (BCB), FM BCB, high fidelity audio, and television equipment in addition to shortwave and scanner receivers.



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Included are: electric motors, a microwave oven, loose tie-wires on AC mains transformers (on the pole outside the home), and electrical space heaters.

Many different forms of appliances were indicted, including (oddly enough) a dishwasher that has an SCR controller inside to turn it on and off, a garbage disposal unit under the complainant's sink, a garage door opener, and the most raucous door bell-chime I've ever heard.

Two forms of noise seem to be present. First, the harmonics of the 60 Hz power line waveform are present throughout the spectrum. If the power line produced a pure sinewave, then this would not occur. But the power line waveform is distorted, so has harmonics. Because the power levels are so high, the significant harmonics form a "comb" spectrum every 60 Hz high into the radio frequency spectrum. Second, any item that sparks (e.g., electric motors) will produce static signals much like lightning does.

Dealing With AC Power Line EMI

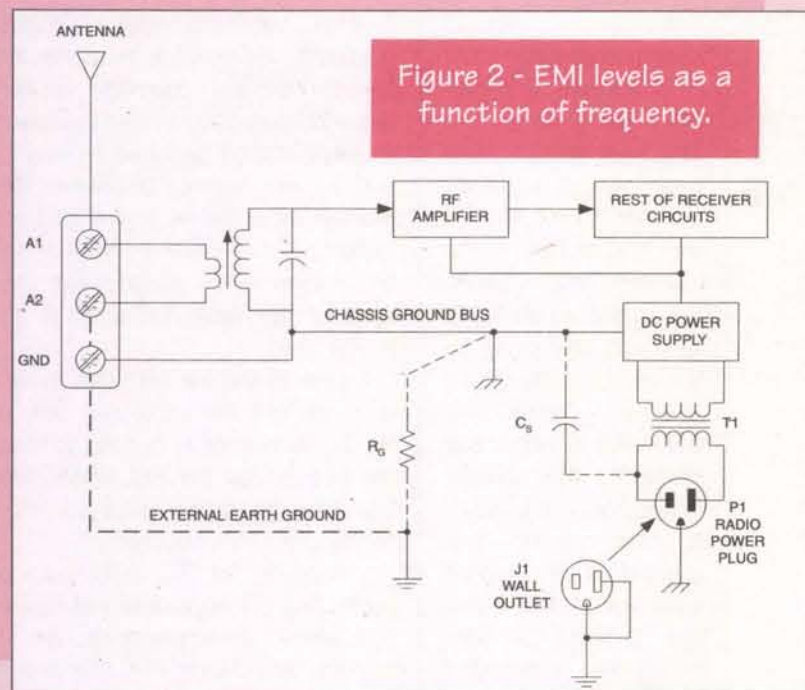


Figure 2 - EMI levels as a function of frequency.

Figures 2 and 3 characterize this noise emission in two different ways. Figure 2 shows the relative level in arbitrary units versus frequency. Typical intensity levels might run from a fraction of a microvolt per meter ($\mu\text{V}/\text{m}$) to nearly 500,000 $\mu\text{V}/\text{m}$, depending on the source (which is why Figure 2 is in "arbitrary voltage units").

Note in Figure 2 that the distribution of signal intensity is uneven throughout the spectrum. The levels will be extremely high in the VLF portion of the spectrum, and fall off almost evenly up into the UHF spectrum. If you tune into the AM BCB or medium wave bands (up to about 7 MHz or so), then you will note a high

hash level. It is more intense on the lower frequencies, but annoying well into the shortwave bands.

Figure 3 characterizes the 60 Hz power line EMI problem as a function of distance from the noise source. Again, because the actual values of the distance and signal strength vary with your particular situation, relative units are used in Figure 3. Note that the 500 KHz (bottom of AM BCB) strength does not fall off nearly as fast as the higher frequency components.

This fact leads us to a strategy for finding the source. Start at the lowest frequency, and tune to higher frequencies until the noise just begins to disappear. You want it

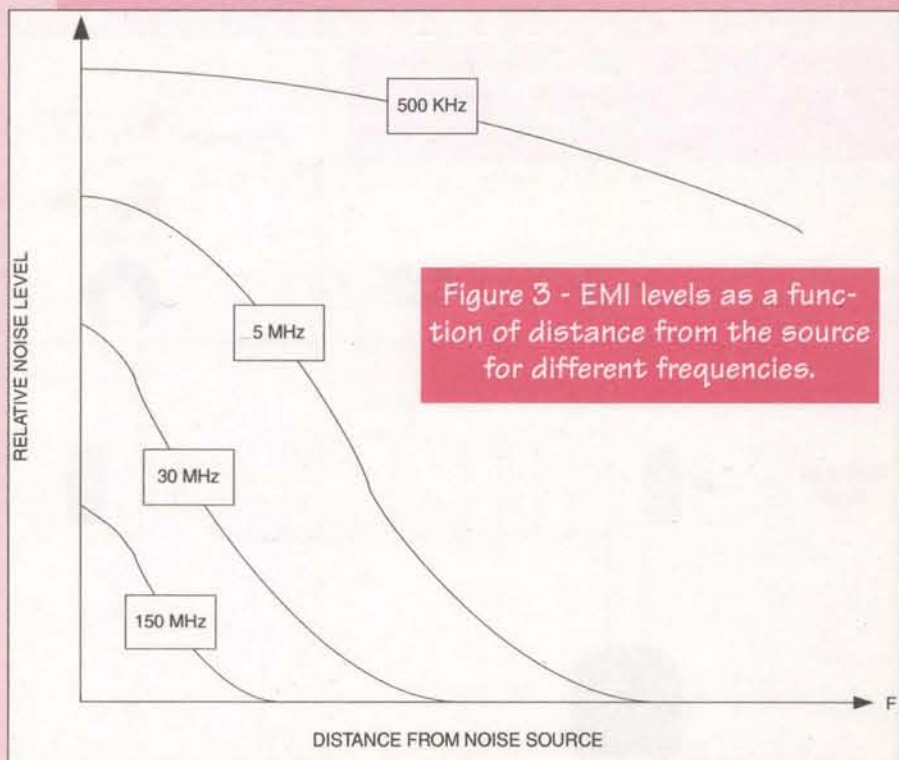


Figure 3 - EMI levels as a function of distance from the source for different frequencies.

audible, but barely so. Walk, drive, or turn your antenna in first one direction and then the other to see in which direction an increase is noted. Go in that direction until the signal is again strong.

At that point, pick another higher frequency at which the noise is just barely audible and repeat the process. This process is repeated at successively higher frequencies until you are very, very close to the source. At that time, start looking for likely culprits.

Once the source is located, it can be dealt with by one or more methods. If it is the power line (loose connections raise hob with reception!), then contact the power company and ask them to fix it ... demand it if they balk. If it turns out to be an appliance, then either the appliance needs repair or some sort of filtering is needed.

Unless it is your appliance, I recommend having a professional technician actually do the work. If you do the necessary work on your neighbor's appliance, then you will be "married to it" if anything at all goes wrong even in the distant future (some people will use any excuse to get someone else to pick up their tab).

Things To Do At Your Receiver

You may or may not be able to do something about

the noise source (which is always the best solution!), but there are some things that you can do about the problem at your receiver. Let's take a look at some of those problems.

First, let's look at one of the sources of the problem. Let's assume

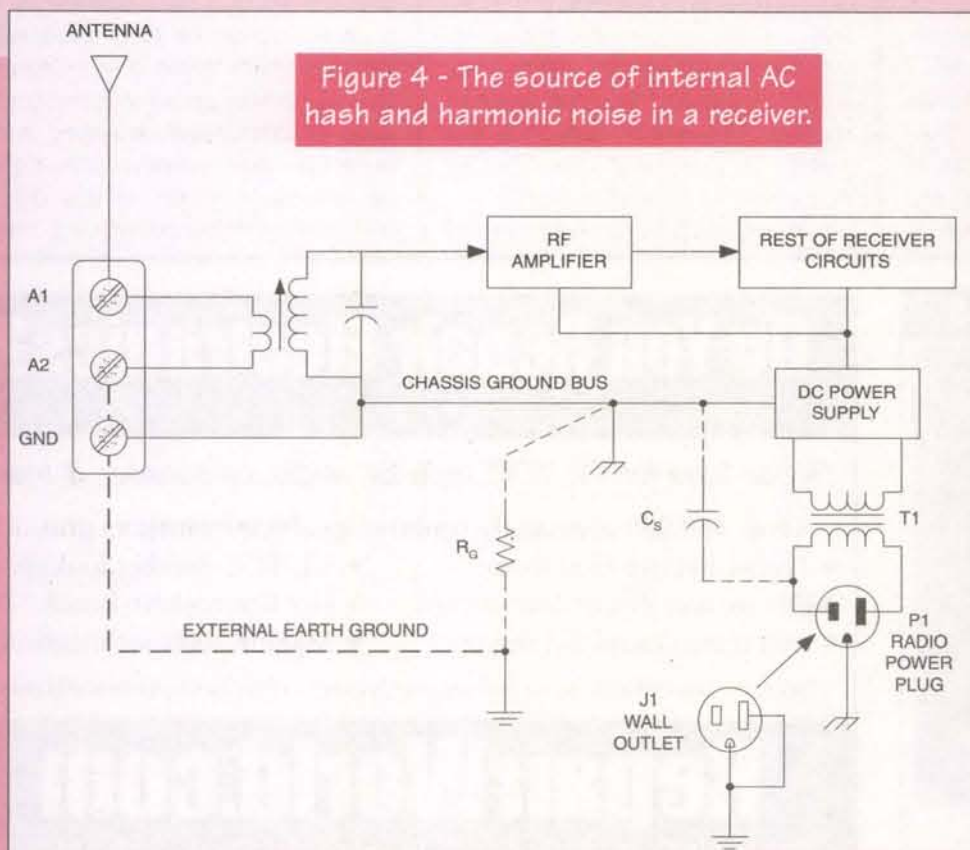


Figure 4 - The source of internal AC hash and harmonic noise in a receiver.

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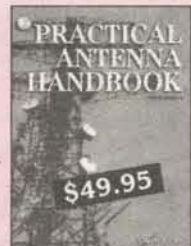


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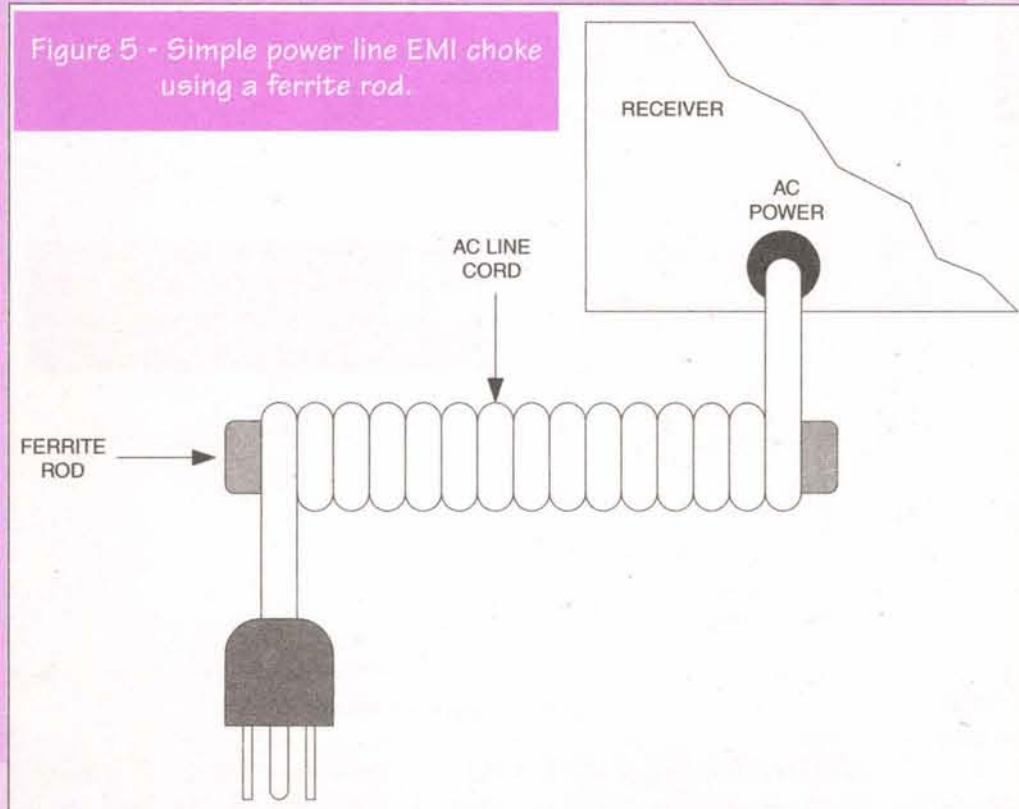
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Figure 5 - Simple power line EMI choke using a ferrite rod.



a generic shortwave or scanner receiver with a three terminal antenna connector (Figure 4).

The antenna terminals include A1 and A2, which lead to the antenna input circuitry, and GND which is the chassis ground (and zero-signal common). There is normally a coupling path between the AC power wiring and the chassis of the receiver.

The capacitance between the AC power wiring and the chassis forms a path, represented by capacitor CS in Figure 4. This means that noise-laden AC is passed onto the receiver chassis, where it can be coupled into the RF amplifier and the rest of the circuit due to

common ground impedances (RG).

Assume first that the external antenna is attached to A1, and that both A2 and GND are not connected. In this circumstance, the ground loop voltage developed across RG is seen as a valid signal by the receiver. The radio chassis is eventually grounded to earth, but through the power connectors (P1 and J1), to the power line ground at the service entrance to the building. Because of wire resistance, connector blade resistance, and the fact that your service entrance ground might be poor for RF, the value of RG can get quite high.

The solution: add an external ground connection to the receiver the way the instruction manual told you to do — strap A2 to GND, and then through a heavy conductor to a proper ground rod buried in the earth. That may eliminate a large part of the power line hash without further work.

AC Power Cord Chokes

Now let's assume that the receiver is properly grounded, but that a high noise level still exists. It may be that the RF components are riding into the receiver via the power lines, and then radiated into the sensitive circuitry. The way to deal with this problem is to eliminate them before they enter the receiver cabinet.

It is often hard to diagnose this

problem, but if the receiver is battery powered, the problem is easier. My favorite general coverage receiver has a DC connector on the rear panel to allow it to be operated from a 12-volt battery source. Disconnect the receiver from the AC power line and operate it from the battery. If the noise level drops appreciably, then suspect the entrance path is the power cord.

One of the easiest ways to deal with the problem is to use only as much power cord as needed to reach the outlet. Coil the rest of the cord into a six-inch diameter loop as close to the chassis as possible.

A species of "RF choke" can be built using the approaches of Figures 5, 6, and 7. The simplest approach is to wrap the receiver's AC power cord around a ferrite rod (Figure 5) as close as possible to the power entrance on the rear panel of the receiver.

Any of several ferrite rods can be used, but the Amidon Associates R61-050-750 is appropriate. Wrap as many turns as will fit onto the 7.5-inch rod, and then secure them with tape (they have a tendency to come unwrapped). There should be enough cord left to plug into the outlet, but even if you have to use an extension cord, wrap as many turns as will fit onto the rod.

A superior approach to the same idea is to use a toroid core as shown in Figure 6. Use one of the larger toroid cores (the kind used for making kilowatt and up BALUN transformers) so that the relatively thick coaxial cable can be accommodated. Wrap as many turns of the power cord as possible onto the toroid core. Note one thing well, however, with the power plug connected this might be impossible to do. If you don't want to modify the power cord, then

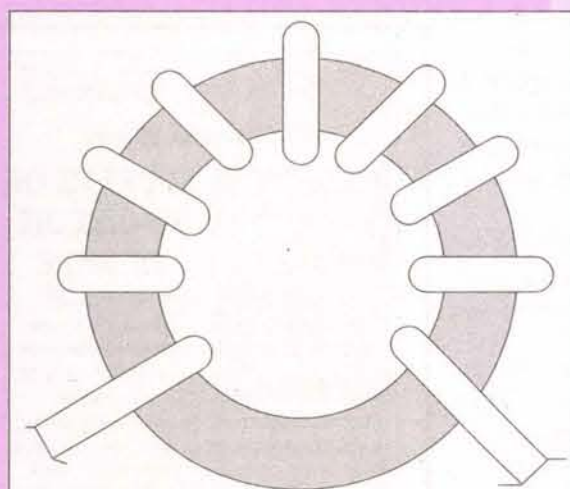


Figure 6 - EMI choke using toroid core.

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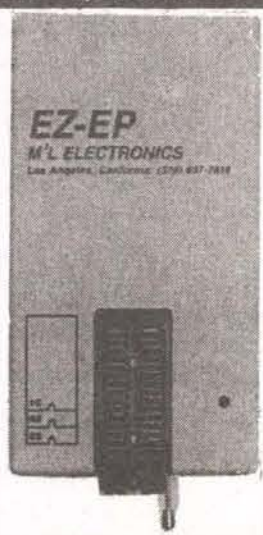
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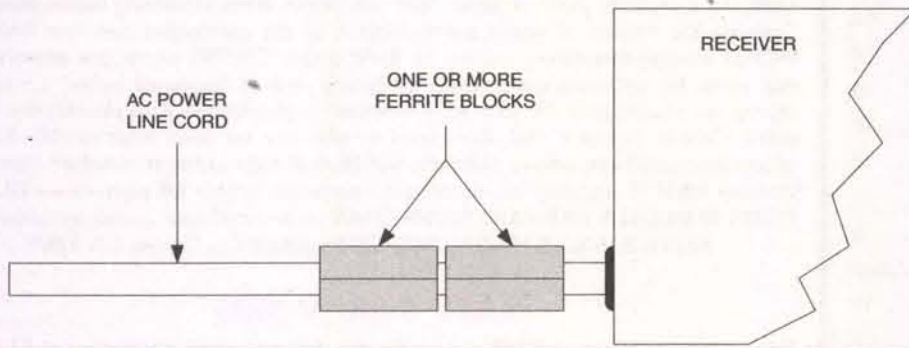
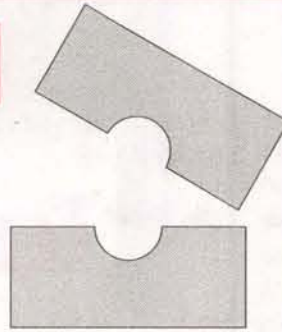
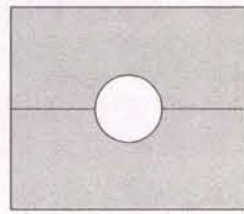
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Figure 7 - EMI choke fashioned by clamping ferrite blocks onto the AC power cord.



you might want to either use the ferrite rod approach, or a ferrite block as shown in Figure 7.

Two views of a ferrite split block are shown in Figure 7A. These blocks come in two halves, each of which is notched such that when put together they form a hole. The application of these blocks is shown in Figure 7B. The blocks are clamped onto the receiver's AC power cord as close as possible to the rear panel of the receiver. Once the blocks are clamped together, they can be secured with tape. In some cases, only a single split block is needed but, in severe cases, two or more split blocks may be added in series. These blocks act like RF chokes, so will snub the higher frequency components while not affecting the 60 Hz AC power.

Ferrite split blocks are available in a number of sizes and shapes to accommodate a number of different forms of cord. Some are flat to allow clamping onto computer ribbon cable, in case a digital device such as a computer is the noise culprit.

AC Power Line Filters

Another way to deal with the

problem of EMI carried into the receiver on the AC power line is shown in Figure 8. The idea here is to use a low-pass filter in series with the AC power line so that the RF components are snubbed out, leaving the 60 Hz to pass unimpeded.

Several filter designs are popular. Some of them use separate pi-section filters in both the hot and neutral lines, while the other uses a pair of coupled coils in a common mode arrangement such as Figure 8.

This design uses a ferrite rod such as the Amidon Associates R61-050-750 to form L1A and L1B. The turns are wrapped onto the cord with a size of AC power wire appropriate to the size. For the maximum power levels, use #12 AWG solid wire intended for AC power wiring applications. The turns for L1A and L1B are wound in the bifilar manner (Figure 9).

The capacitors used in the filter of Figures 8 and 9 should be rated for 125 volt AC service. Ordinary 600 volt or 1,000 volt capacitors are not suitable because they are not rated for constant application of 125 volts AC power line voltage. A typical rating for C1 through C4 is 0.0047 μ F to 0.05 μ F (0.01 μ F typical) at a volt-

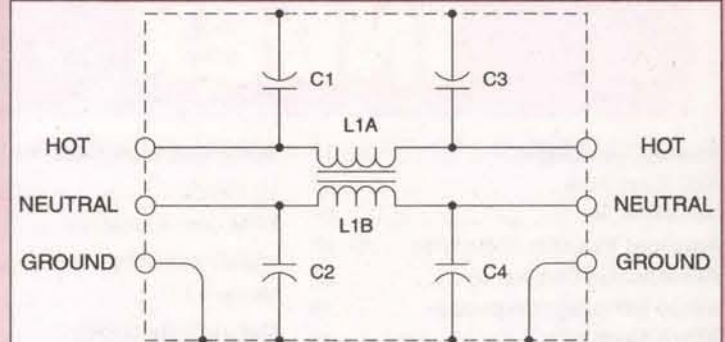


Figure 8 - AC power line EMI L-C low-pass filter (see warning in text).

age rating of 125 volts AC, and 1,400 volts DC (tested to at least 2,800 volts DC). Electronic parts catalogs are a good guide to suitable types of capacitor.

SAFETY NOTE:

Working with AC power lines is dangerous. Accidental contact with the line can kill you. Improper wiring or a bad selection of components, or improper construction methods can create both electric shock and fire hazards. It is highly recommended by the author, editor, and publisher that you select a commercially made, UL approved AC line RF filter made for this purpose rather than homebrew your own. If your receiver uses the same kind of square AC power receptacle that is found on computers, then you can find a replacement for the chassis receptacle that has an EMI filter built in.

Special Case

About five years ago, I had a problem at my house that created AC power line hash in great quantities, and also affected my AC power service. For several years, I listened to an evening shortwave broadcast in the 5-6 MHz band, and on Saturday night to WSM in Nashville (650 KHz AM) ... good country music is where you find it (There! I'm out of the closet ... a Carr's a hillbilly music fan!).

The hash started one summer, and continued into the fall, ruining many evenings of listening. It had an average signal strength of S7 to S8 on my Drake R-8 receiver S-meter. I suspected that the problem was on the power pole,

but the local power company could not find any problem.

That winter, a strange thing started happening with the lights in my home. Whenever any heavy current drain (refrigerator, freezer, furnace) would turn on, the lights would nearly double in brightness. Notice anything odd? Lights should dim, not get brighter, when a heavy load is turned on.

This time, the power company did find a problem. The technician came to the Carr house about 10 o'clock one evening, when the effect was nearly constant, and found that the neutral line connection to my AC power line service was loose.

The fellow raised his "cherry picker" basket up to the power pole, at the point where my service tap was located, and used the largest crimping tool I've ever seen to repair the connection. The lights went back to normal, which was a blessing.

But the next evening, I noticed that the S-8 noise level was down somewhere near decimal dust ... the hash was gone. I suspect that the loose connection was causing the hash all along. Indeed, the power company could have fixed the service problem earlier if they had taken the EMI problem seriously. The hash was merely a prodromal symptom of the service problem!

Conclusion

AC power line harmonics and spark hash can create havoc with radio reception. But with the methods discussed in this article, you will be able to overcome many of these problems. **NV**

Connections ...

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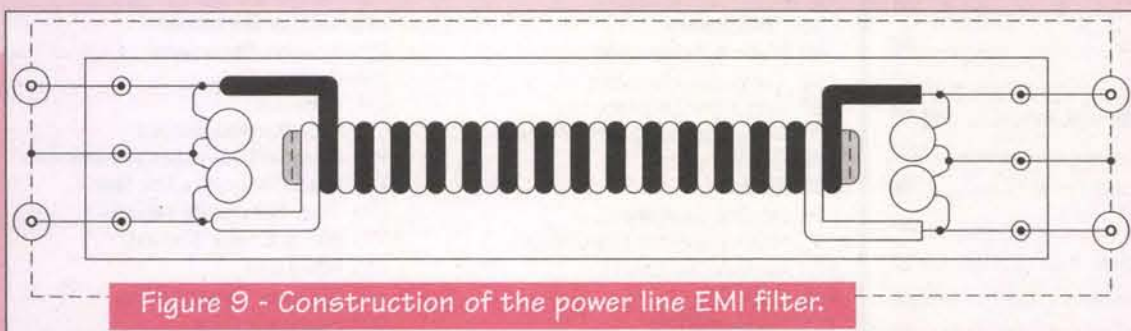


Figure 9 - Construction of the power line EMI filter.

on the power pole,